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(54) Descrambling system for television signals scrambled by active line rotation

(57) A descrambler for descrambling a signal scrambled by active line rotation (i.e. by interchanging two portions of a line, Fig 1) has a pair of line stores 8 connected to a descrambling control input 13 (receiving data on the cut point between the two portions) to effect the line rotation. A tilt measurement circuit 3 measures line tilt, namely any overall change in video amplitude level across a line, and compensates by generating 4 a converse ramp signal which is added 5 to the video signal. The ramp signal is generated to ten-bit accuracy whereas the video signal has only eight bits. The two least significant bits are accumulated 6, 7 on a sample-by-sample basis to effect error feedback. The beginning and end of the received line comprise overlapping signal portions, and the tilt measurement is effected by comparing the overlapping signal portions. Instead of simply averaging the samples in each of these portions a low-pass filtering function is applied to reduce the effect of noise, the filter coefficients being stored in a store 22 and applied to a multiplier 21.

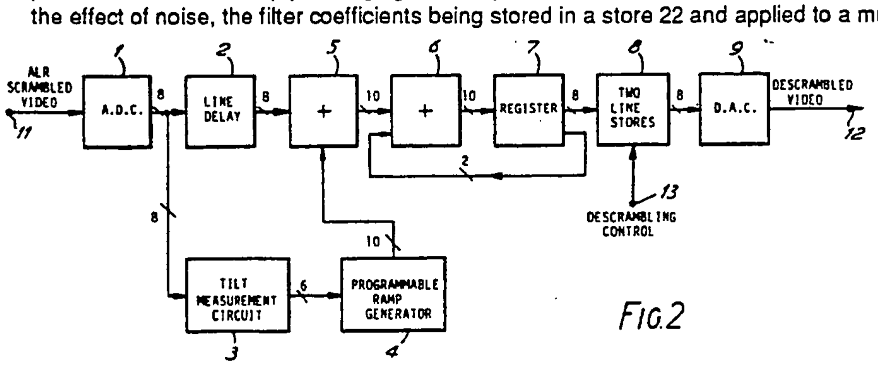

FIG.2

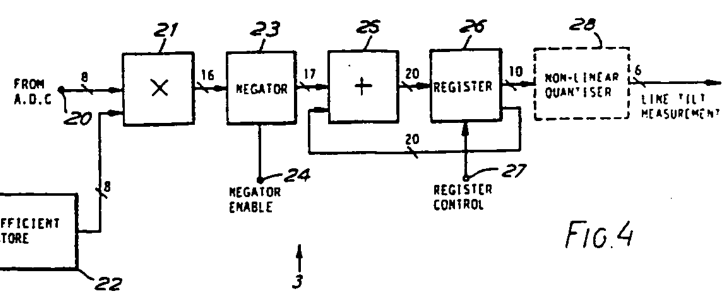

FIG.4

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy

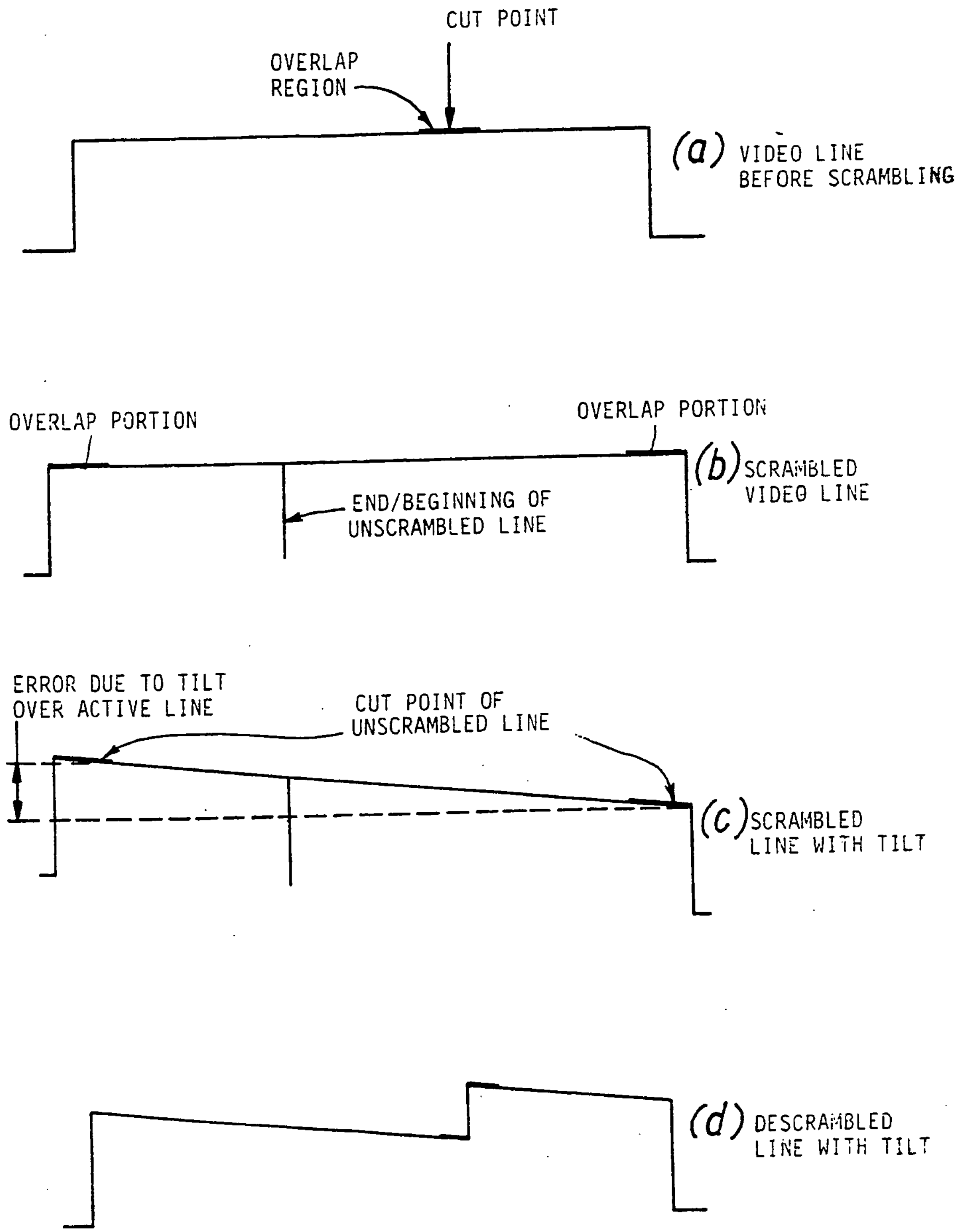
CUT POINT
OVERLAP REGION
(a) VIDEO LINE BEFORE SCRAMBLING
OVERLAP PORTION
OVERLAP PORTION
(b) SCRAMBLED VIDEO LINE
END/BEGINNING OF UNSCRAMBLED LINE
ERROR DUE TO TILT OVER ACTIVE LINE
CUT POINT OF UNSCRAMBLED LINE
(c) SCRAMBLED LINE WITH TILT
(d) DESCRAMBLED LINE WITH TILT

FIG.1

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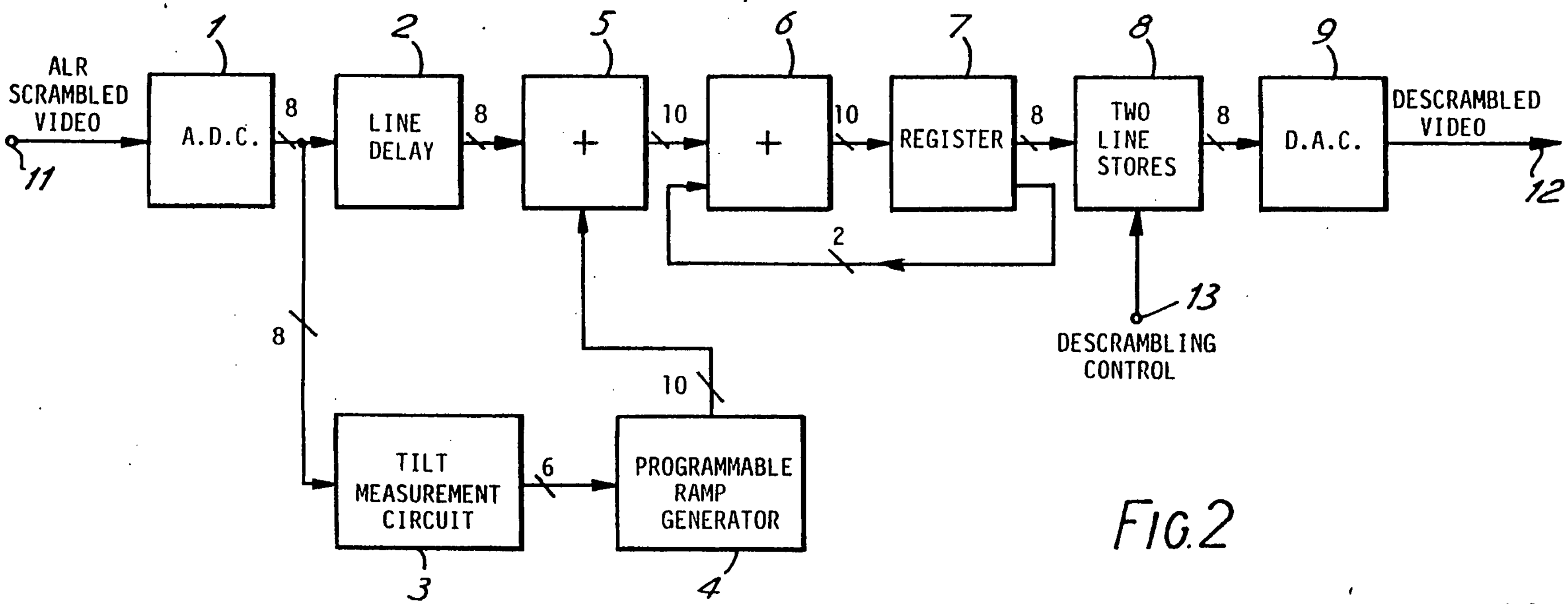
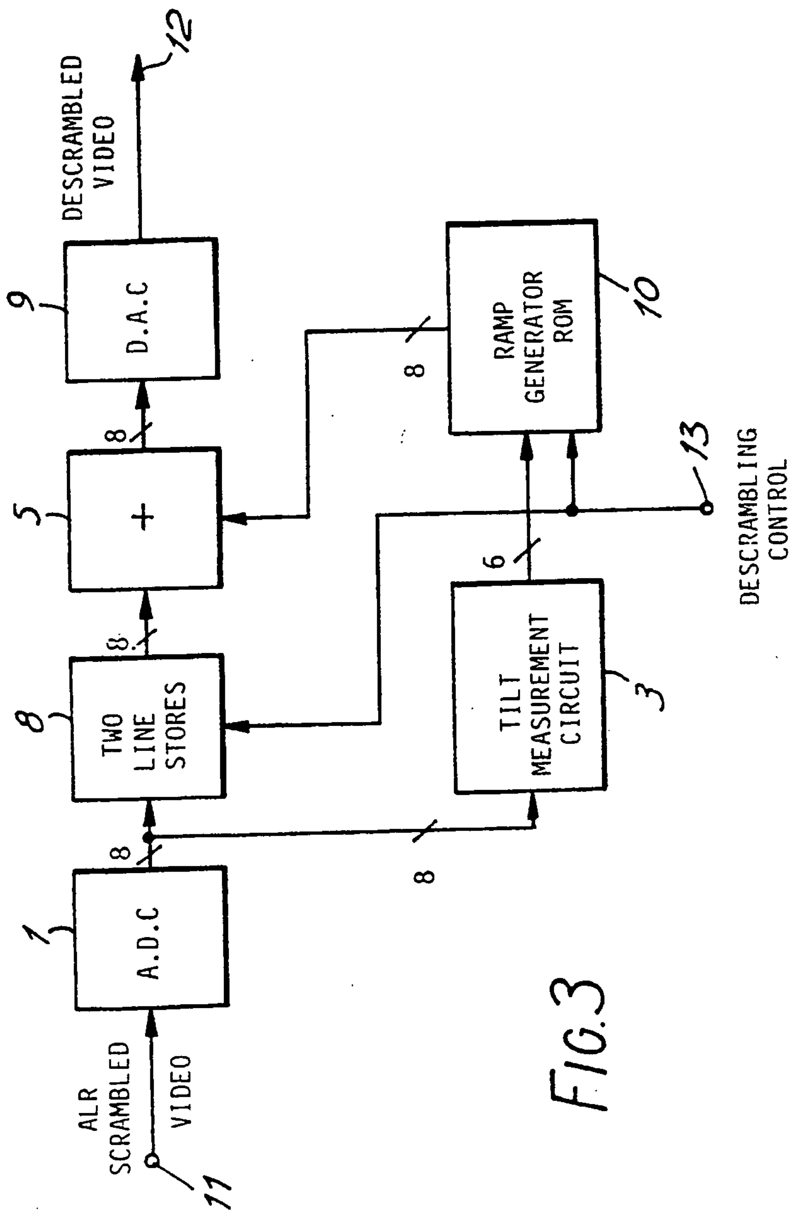


FIG.2



ALR SCRAMBLED VIDEO
11
A.D.C
1
8
8
TWO LINE STORES
8
8
+
5
8
D.A.C
9
DESCRAMBLED VIDEO
12
TILT MEASUREMENT CIRCUIT
3
6
RAMP GENERATOR ROM
10
8
DESCRAMBLING CONTROL
13

FIG.3

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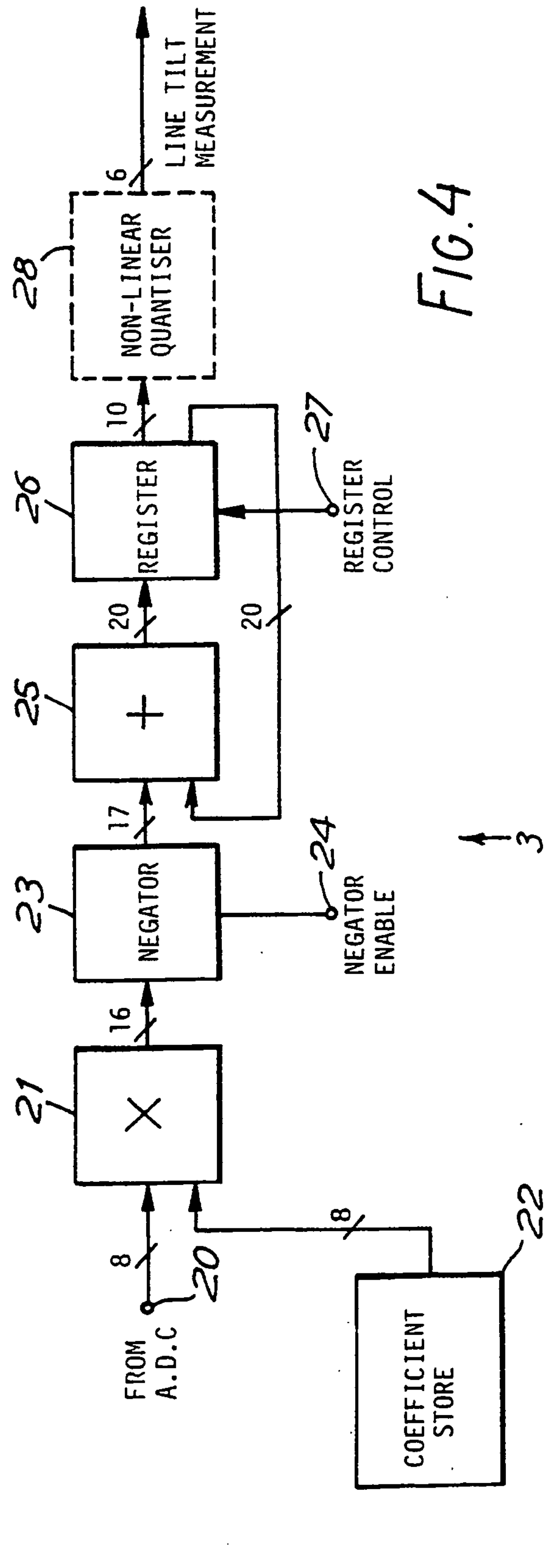

FIG. 4

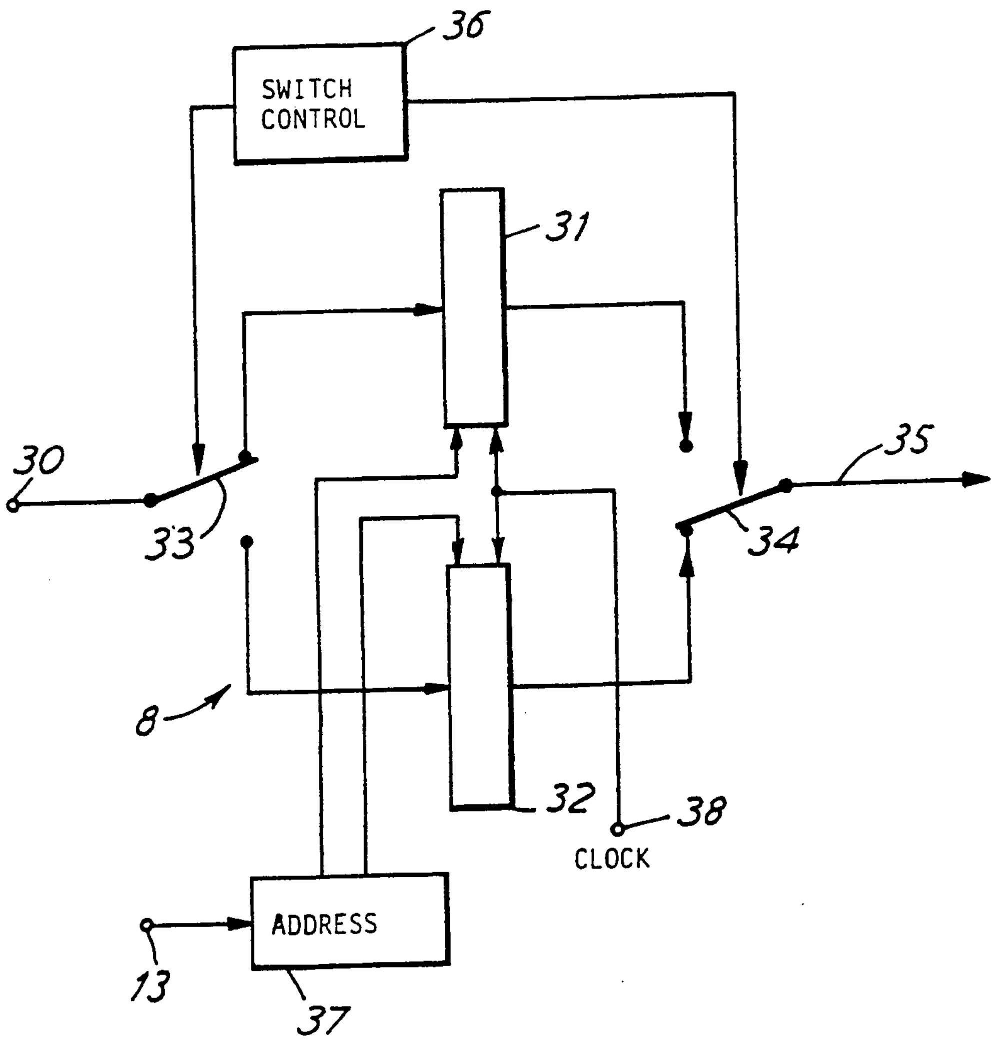

FIG.5

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DESCRAMBLING AND LINE TILT MEASUREMENT SYSTEMS FOR BROADCAST TELEVISION SIGNALS

This invention relates to a descrambling system and a line tilt measurement system for broadcast television signals.

For scrambling broadcast television signals, for example in a subscription television service, it has been proposed to use a scrambling procedure known as Active Line Rotation (ALR), see BBC Research Department Report 1985/12 "DBS PAY TELEVISION: Picture signal scrambling", M.J. Knee, October 1985. In ALR, the active line portion of the video signal, namely the portion carrying picture information as opposed to the blanking portion, is cut at a point intermediate its ends and the two resultant parts of the line are transmitted in the reversed order, that is the second part of the line is transmitted before the first part of the line. There is a small overlap at the join which is desirable to facilitate joining up of the two halves of the line at the receiver. This is illustrated at (a) and (b) in Figure 1. The cut point is essentially randomly selected in a way that can be reproduced accurately at the receiver. Typically the overlap constitutes about one or two microseconds of the active line in a conventional line length of about 64 microseconds. This represents of the order of 20 samples.

Such a system was originally proposed in the context of MAC type signals for FM satellite transmission. However, the principles are also applicable to other television standards including PAL, NTSC and SECAM, for terrestial broadcasting.

Because of the less-than-perfect low frequency response of the signal distribution network to the transmitter and the transmitter itself there is in practice with terrestial broadcasts frequently a slight variation in signal amplitude level along the scanning line, typically of a few percent, which is normally not noticeable to the viewer. This is known as 'line tilt' and is illustrated on an exaggerated scale at (c) in Figure 1. However, when ALR is used, the portions transmitted at the ends of the transmitted line are descrambled at the receiver so as to be immediately adjacent each other at an intermediate point on the line. This is illustrated at

(d) in Figure 1. The "step" which occurs at the cut point due to line tilt does become visible, despite the fact that it arises at a different point on each line, and does degrade the subjective image quality. The line tilt may therefore require correction at the receiver.

It has been proposed by M. Christiansen, et al, in a paper "A video scrambler/descrambler concept for the PAL format" published in the Journal of the Institution of Electronic and Radio Engineers, Vol. 57, No. 1, pages 27 to 35, January/February 1987, to correct for tilt by comparing the beginning and end of the received line, see page 34 left hand column. If there is an overlap, the beginning and end of the received line should correspond to the same data. Thus any difference is representative of the amount of line tilt, and appropriate compensation for the variation in signal amplitude can be made.

Another method of line tilt measurement is described in European Patent Application No. 0 242 469 A1, but this involves the addition of reference amplitude levels to the signal.

BBC Research Department Report 1987/12 "Accommodating the Residue of Processed or Computed Digital Video Signals within the 8 Bit CCIR Recommendation 601", M.G. Croll, V.G. Devereux and M. Weston, published September 1987, describes a method of rounding down the number of bits in a digital video signal in such a manner that the resulting quantising errors have a lower visibility than that of errors given by simple truncation. Where signal processing such as filtering or fading is applied to say an eight bit video signal, a very large number of fractional bits are generated. In the method proposed in that report, the fractional bits caused by such signal processing are accumulated sample by sample until a carry bit is generated which is then added to the least significant bit output.

We have appreciated that such a fractional bit accumulation method provides particular advantages when used in connection with line tilt correction in an ALR descrambler, in reducing the visibility of the contouring caused by the tilt correction.

We have also appreciated that the sensitivity of the system to noise can be improved by providing a filter function to the

beginning and end of the received line used in line tilt measurement.

The invention in its various aspects is defined in the appended claims to which reference should now be made.

The invention will now be described in more detail, by way of example with reference to the drawings, in which:-

Figure 1 (referred to above) illustrates the way in which line tilt causes an amplitude discontinuity when active line rotation scrambling techniques are used;

Figure 2 is a block diagram of the relevant part of a descrambler used in accordance with this invention at a terrestial broadcast receiver;

Figure 3 is a block diagram of a modification of the descrambler of Figure 2;

Figure 4 is a block diagram illustrating a tilt measurement circuit used in Figures 2 and 3; and

Figure 5 is a block diagram illustrating the two line stores used in Figures 2 and 3.

The descrambler illustrated in Figure 2 includes an input 11 for receiving an ALR scrambled video signal. An analogue-to-digital converter (ADC) 1 is connected to the input to supply a digital signal which is applied to a line delay 2 and a line tilt measurement circuit 3. A programmable ramp generator 4 is connected to the output of the tilt measurement circuit 3 and generates a ramp waveform across a line which is exactly equal and opposite to the measured tilt and thus compensates for tilt such as shown in Figure 1 at (c). The compensating ramp waveform is added in adder 5 to the output of line delay 2. The line delay is necessary because the line tilt measurement can not be made until the end of the line, whilst the correction must be applied from the beginning of the line.

Exact correction of line tilt is possible because the processing is digital. Whereas the ADC 1 works to eight bit accuracy, the ramp is generated to more than eight bits accuracy, e.g. ten bits, to avoid visible contouring. The output of adder 5 is therefore applied to a further adder 6 the output of which is applied to a register 7. The register 7 passes the eight most

significant bits to its output and recirculates the two least significant bits to the adder 6. In the adder 6 the remainder or residue bits are therefore accumulated from sample to sample as described in BBC Research Department Report 1987/12. When the accumulated residue generates a 'carry' bit this then affects the eighth bit and is passed through to the output of register 7. This error feedback reduces the visibility of any contouring.

The signal from register 7, with tilt corrected, is applied to a descrambler including a pair of line stores 8, the output of which is applied to a digital-to-analogue converter (DAC) 9, and the output 12 of which in turn constitutes the output of the circuit. The descrambler is controlled by a descrambling control signal received at an input 13 which identifies the cut point of the line.

A modification is shown in Figure 3. This represents a simplification of the circuitry required compared with Figure 2, relying on the fact that the error feedback can be applied to the correction signal alone, because the correction signal is the only source of the ninth and tenth bits. Thus correction signals can be precalculated for all the values of tilt that it is desired to correct and stored in a ROM (read-only memory) 10 which receives the output of the tilt measurement circuit 3. The ROM also receives the descrambling control signal from input 13 and in response to that signal makes the second part of the ramp available before the first. Thus the correction can be applied to the signal after it has been descrambled, i.e. rotated back. The correction signal supplied from the ROM has eight bits accuracy. In precalculating the stored corrections the accumulation of the least significant bits starts at the beginning of the line as received, that is before re-ordering takes place.

In Figure 3 the separate one-line store 2 is unnecessary as the stores 8 provide the required delay for operation of the tilt measurement circuit. Therefore the stores 8 are connected directly to the output of the ADC 1 and the output of stores 8 is applied to adder 5 which also receives the correction signal from ROM 10. The output of adder 5 is applied to DAC 9.

In both the systems described it is seen that the variation in signal level along a line is determined in circuit 3 to provide a

measurement of line tilt. The two portions of the video line are re-ordered about the cut point in line stores 8 in response to the signal at the descrambling control input 13. The video signal is digitised to eight-bit accuracy. A tilt correction is applied to the video signal, and the correction is basically determined to an accuracy of ten bits, i.e. a greater number of bits. The two least significant bits, i.e. the residue bits, are accumulated from sample to sample, with any carry bits being added in, either directly to the video signal (Figure 2) or incorporated in the correction (Figure 3).

The line tilt measurement circuit 3 used in Figures 2 and 3 may take the form shown in Figure 4. An input 20 receives the output of the ADC 1 which it applies to one input of a multiplier 21. The other input of the multiplier is connected to a coefficient store 22. The multiplying coefficient can be different for each sample along the line and by having different coefficients it is possible to low-pass filter the signal. This improves the reliability of the line tilt measurement in the event that noise has been added to the signal after the scrambler, for example when receiving a weak signal. Other methods of low-pass filtering may of course be used.

Typically nineteen overlapping samples may be used, in any event a value of the order of 10 or greater is preferred. These may simply be averaged, which is equivalent to saying that the nineteen coefficients stored in store 22 are all equal. However, to reduce noise visibility we prefer to provide a filtering function with nineteen non-uniform coefficients. Various low-pass filtering functions may be used which will generally be symmetrical about the centre sample, the tenth in this case. Two examples may be proposed:

(a) based on a raised cosine function with the ten coefficients:

0.02 0.10 0.21 0.35 0.50 0.65 0.79 0.90 0.98 1.00

(b) based on a truncated (sin x)/x function with the ten coefficients:

-0.10 -0.19 -0.22 -0.16 0.00 0.23 0.50 0.76 0.94 1.00.

Reducing the noise will reduce apparent streaks arising from line to line due to errors in tilt measurement on successive lines.

The output of multiplier 21 is applied to a controllable

negator 23. A negator is the digital embodiment of an inverter i.e. it multiplies by minus one. The negation is selectively applied in accordance with an enabling signal received at an input 24. The output of the negator 23 is applied to an adder 25 which is arranged in a recirculating loop with a register 26 which is controllable in accordance with a signal received at an input 27. The controllable negator 23, adder 25 and controllable register 26 form a unit which can either accumulate or subtract a number from the total held in the register 26. When the start of the active line passes through the system the register is cleared and then enabled for a desired number of samples, N, corresponding to the length of the overlap shown in Figure 1. This allows the average level of the start of the video signal to be determined. The register is then disabled until N samples before the end of the active video line, when it is re-enabled and the video signal is negated in negator 23. This allows the average level of the end of the active video line to be subtracted from the level at the start of the active video line. Since, due to the overlap, the same signal is present at the two line ends coming out of the scrambler, any difference calculated by this method is a measure of line tilt. To make the measurement easier the overlap could be slightly larger than would otherwise be the case.

By making an average over the difference signal of a number of samples the line tilt can be calculated to an accuracy of greater than one least significant bit. The greater accuracy in this measurement allows the line tilt to be totally corrected.

The output of the register 26 can constitute the output of the line tilt measurement circuit. However, if the amount of tilt is large, there may be no advantage in correcting it exactly; an approximate correction may be equally good. In this case, in the example of Figure 3 fewer correction signals would need to be stored and so the ROM could be smaller. The output of the tilt measurement circuit 3 would be passed through a non-linear quantiser 28 before being applied to the ROM 10.

Figure 5 illustrates diagrammatically how in principle the line stores 8 may be constructed. Two line stores 31,32 are connected through an electronic distributing switch 33 (or demultiplexer) to

the input 30 and through an electronic selector switch 34 (or multiplexer) to the output 35. The switches 33,34 are operated by a switch control circuit 36 to connect one store to the input and the other to the output and to reverse the connection between lines. An addressing circuit 37 connected to the control input 13 ensures that the signals are read out of the store locations in a different order from that in which they are written in so as to perform the necessary re-ordering. Appropriate clock pulses are applied from an input 38.

In Figure 5 the line stores 31,32 read and write on alternate lines, i.e. while one is reading the other is writing. The address sequence for the writing operation (say) is in the normal sequence while the address sequence for the reading operation is "rotated" so as to provide the required line rotation. That is to say the second part of the stored line is read out before the first. The address generator 37 is thus in two halves with one half controlling the writing operation and the other half controlling the reading operation; the latter half receives the information at terminal 13 defining the cut point for each line.

While the systems have been described in terms of hardware implementation, it will be appreciated that the circuitry may be arranged in many different ways, and many of the operations may be performed in software. In that case the block diagrams are best regarded as flow charts indicating the necessary steps to be taken.

CLAIMS

1. A method of line tilt measurement in a video signal, comprising multiplying samples at the beginning of a received line by respective coefficients and multiplying the samples at the end of the line by respective coefficients, and accumulating the resultant with the samples at the beginning and the end of the line being accumulated in opposite senses, the coefficients being non-uniform to define a desired filtering function.

2. A line tilt measurement circuit for determining line tilt in a received video signal, comprising:

a signal input for receiving successive samples of an input video signal;

means for multiplying the input samples at the beginning of a received line by respective coefficients and for multiplying the input samples at the end of the line by respective coefficients and for accumulating the resultant with the samples at the beginning and the end of the line being accumulated in opposite senses; and

a coefficient store for storing non-uniform coefficients for use in the said means whereby a desired filtering function is obtained.

3. A circuit according to claim 2, in which the beginning and end of the received line correspond to overlapping portions of a signal scrambled by active line rotation (ALR).

4. A circuit according to claim 3, in which the overlap portion comprises at least ten samples.

5. A method of descrambling video signals which have been scrambled by active line rotation, the method comprising:

determining the variation in signal level along a line such as to provide a measurement of line tilt; and

re-ordering the two portions of the line about a cut point defined by a descrambling control signal, to provide an n-bit re-ordered signal;

and including the step of:

applying a tilt correction to the video signal, the correction being determined to an accuracy of m bits where m is greater than n, the m - n residue bits being accumulated from sample to sample from the beginning of the received line with any carry bits being added to the signal.

6. A descrambler for descrambling video signals which have been scrambled by active line rotation, comprising:

a signal input for receiving a video signal to be descrambled;

a signal output for providing the descrambled signal;

a descrambling control input for receiving a signal indicating the position of the cut point;

tilt measurement means coupled to the input for determining the variation in signal amplitude along a line such as to provide a measurement of line tilt; and

line rotation means coupled between the signal input and signal output for re-ordering the two portions of the line about a cut point defined by a signal received at the descrambling control input to provide an n-bit re-ordered signal;

and further including:

correction means responsive to the tilt measurement means for applying a tilt correction to the video signal, the correction being determined to an accuracy of m bits where m is greater than n, and the m - n residue bits being accumulated from sample to sample from the beginning of the received line with any carry bits being added to the signal.

7. A descrambler according to claim 6, in which the correction means generates a ramp signal which is added to the video signal prior to the line rotation means.

8. A descrambler according to claim 7, in which the correction means includes means for accumulating the m - n least significant bits of the video signal and adding any carry bits to the video signal.

9. A descrambler according to claim 6, in which the correction means is coupled to the descrambling control input to generate a re-ordered ramp signal which is added to the video signal subsequent to the line rotation means.

10. A descrambler according to claim 9, in which the correction means comprises a memory device containing corrections for various values of tilt, the m - n least significant bits of the corrections having been accumulated and any carry bits added to the correction signal.

11. A descrambler according to any of claims 6 to 10, in which the beginning and end of the received line comprise overlapping signal portions.

12. A descrambler according to claim 11, in which the overlap portion comprises at least ten samples.

13. A line tilt measurement circuit substantially as herein described with reference to Figure 4 of the drawings.

14. A method of descrambling substantially as herein described with reference to the drawings.

15. A descrambler substantially as herein described with reference to and as shown in Figure 2 or 3 of the drawings.

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